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1. How widely available is ethanol today, and how many cars can use it?

The United States ethanol industry produces about 4 billion gallons of fuel ethanol per year from corn grain. About 20 new ethanol plants will come online in 2006, adding another 1 billion gallons of capacity. Current ethanol production is about 300,000 barrels/day.

All U.S. automobiles and light trucks can use ethanol at 10% (E10) without modification. In addition, about 5 million flexfuel vehicles (FFVs) can use 85% ethanol (E85), gasoline or any mixture in between.

Flexfuel technology is cheap, about $200 per car, consisting of improvements to the fuel injector, gas line and gas tank. Eight major auto manufacturers currently offer E85 vehicles. Ethanol has about two-thirds the energy per gallon (76,100 Btu/gal) as compared to gasoline (113,537 Btu/gal), but a much higher octane (100-105). To date, flexfuel technology has been offered primarily in larger vehicles to obtain Clean Air credits. If flexfuel technology and E85 were combined with hybrid technology, all available today, it would be possible to make E85 hybrids which could get hundreds of miles per gallon of gasoline, the rest coming from ethanol.

2. What are the obstacles to expanding the variety of feedstocks available for conversion to ethanol? Are these hurdles mainly market failures and other economic barriers or are they technical in nature?

The national necessity for a large cellulosic ethanol industry is not yet widely recognized. There is a lack of national urgency to make it happen in the time frame needed. High oil prices and global warming have come upon us rather suddenly, and both markets and government institutions are slow to react.

Commercialization of any new technology, and building new industries takes time and investment. Many different technical elements must be discovered, tried and perfected in a context which results in profitable businesses. As an example, it has taken the corn ethanol industry about 30 years to develop from small experimental plants to today's situation of 25-50% growth over the next year or so from the current 4 billion gallons/year.

Ironically, the current success of the corn ethanol industry and the low price of corn are barriers to the investment and risk-taking needed to jump-start the new cellulosic ethanol industry. Corn is currently cheap ($2.50/bushel), and the engineering technology for corn ethanol plants is so good that new plants cost only $1.50 per annual gallon of capacity. In contrast, cellulosic ethanol plants using current technology cost about 6 times that much for the same ethanol capacity (Iogen estimates).

Specific technical and logistical hurdles include
(1) transportation of large volumes of low density biomass, e.g. 27 truckloads of switchgrass to make 1 truckload of ethanol;
(2) the need for safe, rapid pretreatments to process large volumes of raw biomass into cellulose and other components;
(3) large quantities of cellulase and other enzymes to convert cellulose to glucose for making ethanol. For example, a single 25 million gal/yr ethanol plant would require 2750 tons of cellulase enzymes. Adding just 1 billion gallons of cellulosic ethanol would require 40 such plants, with a total annual cellulase protein requirement of 110,000 tons/yr. For comparison, all U.S. industrial enzymes in 1994 amounted to about half that, 60,000 tons/year.
(4) new ways to solve the conflict between the need to build large plants for economies of scale, and the opposing need to transport low-density biomass over short (< 30-40 mile) distances. Developing technology to enable smaller, cheaper cellulosic ethanol plants would have a large impact on lowering ethanol costs and promoting the widespread local development of biomass resources.

3. What is the largest technical hurdle for each of the following fuels: Corn ethanol, biodiesel, cellulosic ethanol? Does the current federal research agenda adequately address these technical barriers? What actions would most rapidly overcome these technical barriers?

Corn ethanol can be considered a fairly mature industry, in that there is good technology, reliable and experienced engineering firms and plant operators, and plenty of available capital for expansion. The problem for corn ethanol will be that its success will eventually raise the price of corn, and reach the limits of available corn supply. A typical U.S. annual corn crop is 10-11 billion bushels/year, divided among ethanol, food products, animal feed, exports and carryover. A probable limit for the ethanol fraction from corn is about 4 billion bu/yr, which would produce (2.8 gal/bu) about 11 billion gallons of ethanol, or about 6% of our current 140 billion gal gasoline supply.

Biodiesel is a good fuel with standards, great customer acceptance and a small but growing production industry. That industry will double production in 2006 to 150 million gallons. The main problem for biodiesel is limited feedstock. Biodiesel is made from animal fat or vegetable oil feedstocks including soybean oil, rapeseed (Canola) oil, and waste cooking grease. The fats or triglycerides are combined with an alcohol, usually methanol or ethanol, to make biodiesel and glycerol. Because the feedstocks come from food products, they are usually expensive or in limited supply. Given the demand for biodiesel, it would make sense to support federal and private research to greatly expand the production of plant oils, probably through biotechnology.

Cellulosic ethanol is more difficult to make than corn ethanol, because cellulose and biomass are structural materials, unlike corn starch which is a food material. The components of biomass: cellulose, hemicellulose and lignin, have evolved to resist breakdown for many years. However, the abundance of plant matter has driven the evolution of many microorganisms and genes dedicated to breaking down cellulose and extracting the glucose and other sugars. We can harness these genes and organisms to make a variety of petroleum substitutes from biomass, as part of the growing field of industrial biotechnology.

The chemistry, engineering and biotechnology needed to build this industry are complex. Some specific technical hurdles were listed in response to question 2. Researchers at federal labs, notably NREL, ORNL and NCAUR, and at U.S. universities have addressed many of these issues over the years.

Much work has been done outside the U.S., in Canada, Sweden and Japan among other countries. More than half of the necessary knowledge base for biofuels has been and continues to be developed outside the United States. We need to find ways to use the best available technology from around the world, and not assume that our federal labs can provide all the answers, capable and dedicated as they are. We also need to foster training and international collaboration in developing alternatives to oil. Non-OPEC countries including the United States have a common need to develop cheap domestic fuel sources, or else face increasing economic costs and competition for scarce oil, as well as the effects of global warming.

Building a large and successful biofuels industry in the United States will require a sustained long-term commitment and adequate funding on the federal side. We need to leverage federal funds by making more federal support available to small business and commercialization efforts which can then attract venture capital and other nonfederal investment. In this way, we will build a healthy competitive industry with many players and different approaches.

DOE has wisely supported a number of important areas, including pretreatment research, enzyme development, and genomics, but still has a top-down central planning approach which needs to be augmented by more support of other innovative approaches developed outside the central plan. As an example, in 2005 the USDA/DOE Biomass Research and Development Initiative (BRDI) program received over 600 applications for $15 million of funding, or about 12 grants. The DOE SBIR program likewise offers minimal support for innovative projects in cellulosic ethanol and is inadequately funded. Outside grants in the range of $300,000 to $3 million would fill an important gap in enabling startups to demonstrate new technological approaches, and thereby attract the investment necessary for commercialization.

4. Some advocates suggest that biofuels should substitute for 25 percent or more of the Nation's transportation fuel use. Are there market or other barriers that policy might overcome to accelerate realization of the 25 percent biofuels goal?

As indicated above, we need to make this a national priority. The U.S. has achieved economic success in part by using large amounts of fossil fuels per capita. The downside is that we are now particularly vulnerable to price increases and supply disruptions, as well as incurring an increasing energy trade deficit.

To be clear, we need to make not only ethanol as a substitute for gasoline, but all the other hydrocarbons for diesel fuel and jet fuel (Rostrup-Nielsen, 2005), and for industrial chemicals and plastics. The only realistic non-fossil source for these materials is biomass in all its forms. These include energy crops like switchgrass (Gibbs, 1998; Greene et al., 2004), agricultural wastes, paper from municipal solid waste, and forest and wood wastes. Using all of these sources will provide a more diversified fuel and chemical base, and create many thousands of jobs. The United States has substantial cellulosic resources which can be developed if the determination and resources are there (Perlack et al, 2005).

Federal support for university and private R&D is vital, as indicated above. Commercialization, pilot, and demonstration plant subsidies are needed to move toward the goal of smaller and cheaper cellulosic ethanol plants. The level of public and private funding should over time reflect its importance to the United States, which is on a par with curing cancer and the Apollo program. In this case, there will be substantial private funding, once initial efforts begin to show some success. This is part of the "cleantech" investment sector which is growing rapidly.

Another barrier not discussed yet is developing trained people. Biomass research has heretofore been an arcane area pursued by a small number of scientists and engineers in academic and government labs. As with the biotechnology industry, growth brings the need for many people with specialized knowledge in the areas of biomass and biofuels. Dr. Lee Lynd et al. (1999) have recommended graduate programs in biocommodity engineering, including biotechnology, process engineering, and resource and environmental systems. Their paper provides a good overview of this emerging industrial area. Graduate and postdoctoral fellowships for study abroad in these areas would also be helpful in accessing the knowledge resources of other countries.

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Dr. Daniel Gibbs has over 20 years of experience in biological sciences, including 5 years in medical diagnostics, bioinformatics and pharmaceutical R&D at Abbott Labs. He was an invited speaker on biomass ethanol for the American Coalition for Ethanol, and has published a paper on the potential of switchgrass ethanol in the U.S. He was an Associate Professor at DePaul University, where he received an NIH grant in neuroscience. He was an NIH Postdoctoral Fellow at the University of Washington and an NIH Predoctoral Fellow at Stanford. He received a B.A. in Biology from Wesleyan University and a Ph.D. and M.A. in Biological Sciences from Stanford University.

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General Biomass Company

General Biomass Company is an Illinois corporation founded in 1998 to develop and commercialize biomass technologies. We develop biotechnology for renewable fuels, with a focus on cellulase enzymes which are essential for the conversion of abundant cellulose wastes and biomass crops to low-cost glucose for the production of cellulosic ethanol, other biobased chemicals, and plastics.

General Biomass Company is a member of the American Coalition for Ethanol and the Illinois Biotechnology Industry Organization.